

*What Is Claimed Is:*

1. A device comprising:
  - a light source;
  - at least one objective lens proximate the light source;
  - a unitary member proximate the light source having an outer portion and an inner portion, the inner portion connected to the outer portion, the inner portion having a deformable surface; and
  - at least one actuator that is configured to: (1) deform at least a portion of the deformable surface into a curved sectional surface; and (2) move the inner portion relative to the outer portion upon energization of the at least one actuator.
  
2. A device comprising:
  - a light source;
  - at least one objective lens proximate the light source;
  - a unitary member proximate the light source having an outer portion and an inner portion, the inner portion connected to the outer portion, the outer portion having a maximum cross-sectional area of less than about 9 squared millimeters, the inner portion having a deformable surface; and
  - at least one actuator that is configured to: (1) deform at least a portion of the deformable surface into a curved sectional surface; and (2) move the inner portion relative to the outer portion upon energization of the at least one actuator.
  
3. A device comprising:
  - a housing extending along a longitudinal axis between first and second ends;
  - a light source transmitting a light beam towards the second end;
  - at least one objective lens disposed in the housing proximate the second end, the at least one objective lens having a reflective portion that directs the light beam from the light source towards the first end; and
  - a member disposed between the light source and the at least one objective lens, the member having a reflective portion that defines a curved surface with respect to the longitudinal axis in an operative position of the member.

4. A device comprising:
  - a housing;
  - a light source providing a light beam; and
  - means for moving the light beam to a plurality of focal positions laterally and axially on a focal axis defined by the light beam.
5. A device comprising:
  - a housing extending along a longitudinal axis between first and second ends;
  - a light source transmitting a light beam towards the second end, the light source being fixed at a first location in the housing;
  - at least one objective lens; and
  - a member disposed between the light source and the at least one objective lens, the member having a deformable reflective portion that directs the beam through the at least one objective lens to define a first focal point of light away from the housing along a focal axis in a first operative position of the deformable reflective portion and define a second focal point of light on the focal axis in a second operative position of the deformable reflective portion.
6. A device comprising:
  - a housing extending along a longitudinal axis between first and second ends;
  - a light source transmitting a light beam towards the second end, the light source being fixed at a first location in the housing;
  - at least one objective lens disposed at a fixed location in the housing proximate the second end; and
  - a member proximate the second end, the member having a deformable reflective portion that reflects the directed beam through the at least one objective lens to define a first focal point of light away from the housing on a focal axis defined by the directed beam in a first operative position of the deformable reflective member,

and a second focal point of light on the focal axis in a second operative position of the deformable reflective member.

7. A device comprising:

a housing extending along a longitudinal axis between first and second ends, the housing having a maximum cross-sectional area with respect to the longitudinal axis of less than about 9 millimeters-squared;

a light source providing a light beam; and

means for moving the light beam to first and second focal points on a focal axis defined by the beam of light.

8. A device comprising:

a housing extending along a longitudinal axis between first and second ends, the housing having a maximum cross-sectional area with respect to the longitudinal axis of less than about 9 millimeters-squared;

a light source transmitting a light beam towards the second end; and

at least one objective lens disposed in the housing proximate the second end, the at least one objective lens including one diffractive lens and one refractive lens.

9. A device comprising:

an input portion, the input portion transmitting a light beam through the input portion;

a focusing portion that moves the light beam at a plurality of focal positions on a focal axis defined by the light beam; and

a housing extending along a longitudinal axis between first and second ends to enclose the input and focusing portions, the housing having a maximum cross-sectional area with respect to the longitudinal axis of less than about 9 millimeters-squared.

10. The device of any one of claims 3, 4, and 6, wherein the housing comprises a housing having a maximum cross-sectional area with respect to the longitudinal axis of less than about 9 millimeters-squared.
11. The device of any one of claims 3-6, wherein the housing comprises an outer diameter as measured generally transverse to the longitudinal axis of about 1.8 millimeters and extending about 10 millimeters along the longitudinal axis.
12. The device of any one of claims 3-6, wherein the housing comprises an outer diameter as measured generally transverse to the longitudinal axis of about 1.5 millimeters and extending about 10 millimeters along the longitudinal axis.
13. The device of claim 10, wherein the light source, objective lens, and housing are in a fixed relationship.
14. The device in any one of claims 1 and 2, wherein the unitary member comprises a support portion connected to the reflective portion at first and second locations on the support portion that define a tilting axis extending between the first and second locations, the reflective portion having at least a first actuator coupled to the reflective portion to rotate the reflective portion about the tilting axis when at least the first actuator is energized, the reflective portion including at least a second actuator coupled to a surface of the reflective portion to deform the surface towards the light source when at least the second actuator is energized.
15. The device of claim 14, wherein the unitary member comprises at least a third actuator coupled to the reflective portion to rotate the reflective portion relative to the support portion about a tipping axis extending between third and fourth locations when at least the third actuator is energized.
16. The device in any one of claims 3, 5, and 6, wherein the member comprises

a first member mounted to the at least one objective lens, the first member having a generally planar wall portion with a reflective surface that reflects the light beam towards the first end, the wall portion being coupled to at least a first actuator so that upon energization of at least the first actuator, the reflective surface of the wall portion is deformed into a curved reflective surface; and

a second member located between the point light source and the at least one objective lens, the second member including a support portion connected to a reflective portion at first and second locations on the support portion that define a tilting axis extending between the first and second locations, the support portion connected to the reflective portion at a third and fourth locations on the support portion that define a tipping axis, the member having at least a second actuator coupled to the reflective portion to rotate the reflective portion about the tilting axis when at least the second actuator is energized, and at least at least a third actuator coupled to the reflective portion to rotate the reflective portion about the tipping axis when at least the third actuator is energized.

17. The device of claim 16, wherein the tipping axis comprises an axis generally orthogonal to the tilting axis.

18. The device of claim 16, further comprising a base structure disposed in the housing proximate the first end.

19. The device of claim 18, wherein the base structure comprises a ceramic structure having first and second end caps spaced along the longitudinal axis, the ceramic structure having a wall portion connecting the end caps, the wall portion having a wall surface defining an aperture extending through the ceramic structure on the longitudinal axis.

20. The device of claim 19, wherein the ceramic structure comprises an outer surface having at least a curved surface intersecting at least a planar surface to define

a D-shaped cross-section, the curved surface and at least a planar surface extending along the longitudinal axis.

21. The device of claim 20, wherein one of the first and second end caps comprises a planar surface generally transverse to the longitudinal axis on which at least the second and third actuators are located thereon.

22. The device of claim 21, wherein the first, second, and third actuators comprise an electrostatic actuator.

23. The device in any one of claims 1-8, wherein the light source comprises a high-intensity light coupled to an optical fiber extending along the longitudinal axis in the housing to transmit at least one light beam bi-directionally along the length of the optical fiber.

24. The device of claim 23, wherein the optical fiber comprises a single-mode optical fiber that transmits the light beam having a wavelength of about 500 nanometers.

25. The device of claim 23, wherein the optical fiber comprises a single-mode optical fiber extending generally parallel and offset to the longitudinal axis.

26. The device in any one of claims 1-3, 5, 6, and 8, wherein the objective lens comprises at least one diffractive optical element and at least one refractive optical element.

27. The device in any one of claims 1 and 2, wherein the at least one actuator comprises at least one actuator configured to rotate the inner portion relative to the outer portion upon energization of the at least one actuator.

28. The device of claim 21, wherein the at least one refractive optical element comprises three plano-convex optical elements stacked along the longitudinal axis to provide for a numerical aperture of about 0.4 and a focal length of about 1 millimeter.

29. The device of claims 3, 5, and 6, wherein the member comprises a base surface spaced apart from the reflective portion along the longitudinal axis, the base surface having a wall portion extending through the base surface to define a first aperture, the reflective portion having a wall portion extending through the reflective portion to define a second aperture, the first and second aperture being aligned to pass light through the base surface and the reflective portion.

30. The device in any one of claims 3-6, wherein the housing, light source, member, and objective lens are symmetric about the longitudinal axis, the housing having an outer diameter of about 1.8 millimeters and extending about 10 millimeters along the longitudinal axis.

31. The device in any one of claims 3, 4, 5, and 6, wherein the housing, light source, member, and objective lens are symmetric about the longitudinal axis, the housing having an outer diameter of about 1.5 millimeters and extending about 10 millimeters along the longitudinal axis.

32. The device of claim 16, wherein the objective lens comprises at least one diffractive optical element and three plano-convex optical elements stacked along the longitudinal axis, and the first member is mounted on the at least one diffractive optical element.

33. The device of claim 8, wherein the at least one objective lens comprises an objective lens configured to transmit at least one of invisible and visible lights.

34. The device of claim 33, wherein the at least one refractive lens comprises three plano-convex lenses with each lens in contact with at least one other plano-convex lens to provide for lateral chromatic shift of less than 1 micron, axial chromatic shift of less than 4 microns for wavelength of light from 480 nanometers to 600 nanometers,

35. The device of claim 33, wherein the at least one refractive lens comprises three plano-convex lenses with each lens in contact with at least one other plano-convex lens to provide for a contrast response of 1000 line pairs per millimeter with on-axis confocal point spread of about 0.52 micron at full width half-maximum of the main lobe of a graphical representation of an Airy disc.

36. The device of claim 8, wherein the at least one refractive lens comprises three plano-convex lenses with each lens in contact with at least one other plano-convex lens to provide for lateral chromatic shift of less than 1 micron, axial chromatic shift of less than 4 microns for wavelength of light from 480 nanometers to 600 nanometers, contrast response of 1000 line pairs per millimeter with on-axis confocal point spread of about 0.52 micron at full width half-maximum of the main lobe of a graphical representation of an Airy disc.

37. The device of claim 8, further comprising means for focusing a beam of light extending from the at least one objective lenses to first and second focal points on a focal axis defined by the beam of light.

38. The device of any one of claims 7 and 37, wherein the means comprise means for scanning the light beam to at least other focal points lateral to the focal axis defined by the light beam.

39. The device of claim 8, further comprising a member disposed between the light source and the at least one objective lenses, the member having a deformable



reflective portion that reflects the directed beam through the at least one objective lenses to define a first focal point of light away from the housing along a focal axis in a first operative position of the deformable reflective member, and a second focal point of light on the focal axis in a second operative position of the deformable reflective member.

40. The device in any one of claims 3, 5, and 6, wherein the member comprises a support portion connected to the reflective portion at first and second locations on the support portion that define a tilting axis extending between the first and second locations, the reflective portion having at least a first actuator coupled to the reflective portion to rotate the reflective portion about the tilting axis when at least the first actuator is energized, the reflective portion including at least a second actuator coupled to a wall of the reflective portion to deform the wall towards the light source when at least the second actuator is energized, and at least a third actuator coupled to the reflective portion to rotate the reflective portion relative to the support portion about a tipping axis extending between third and fourth locations when at least the third actuator is energized.

41. The device in any one of claims 2, 3, 5, and 6, wherein the at least one objective lens comprises a diffractive lens, the diffractive lens including a reflective portion that directs the light beam from the light source towards the first end of the housing.

42. The device in any one of claims 1-4, wherein the housing is disposed in an environment to obtain an image from the environment, the environment selected from a group comprising one of a biofilm in porous media; nuclear storage facilities; internally in the human body; and externally on the surface of the human body.

43. A dynamic lens comprising:

a unitary member having an outer portion and an inner portion, the inner portion connected to the outer portion, the inner portion having a deformable surface;  
at least one actuator that: (1) deforms at least a portion of the deformable surface into a curved sectional surface; and (2) moves the inner portion relative to the outer portion upon energization of the at least the one actuator.

44. The dynamic lens of claim 43, wherein the maximum cross-sectional area of unitary member is less than 3 millimeters squared.

45. A dynamic lens comprising:

an outer portion;

an optical inner portion connected to the outer portion, the optical inner portion having a base portion and deformable portion spaced apart along an axis, the base portion including a first base surface spaced apart from a second base surface with a first wall portion connecting the first and second base surfaces, the wall portion being disposed about the axis to define a first aperture, the deformable portion including a first surface spaced apart from a second surface along the axis with a second wall portion connecting the first and second surfaces, the second wall portion being disposed around the axis to define a second aperture generally aligned with the first aperture; and

at least one actuator contiguous to the first surface of the deformable portion so that energization of at least the one actuator deforms the first surface into a curved solid sectional surface.

46. The dynamic lens of claim 45, wherein the outer portion comprises a first annular member surrounding the inner portion, the first annular member having first diametrically disposed beam members connecting first annular member to the inner portion to permit rotation of the inner member about a tilting axis generally orthogonal to the axis.

47. The dynamic lens of claim 45, wherein the outer portion comprises a second annular member surrounding the first annular member, the second annular member having second diametrically disposed beam members connecting the second annular member to the first annular member to permit rotation of the first annular member about a tipping axis generally orthogonal to the tilting axis.

48. The dynamic lens of claim 45, further comprising at least another actuator coupled to the inner portion to rotate the inner portion about one of the tilting and tipping axes when at least the another actuator is energized.

49. The dynamic lens of claim 45, wherein the first surface comprises a reflective surface.

50. A confocal optical system comprising:  
a photodetector that generates signals to a graphical display based on detection of light;  
a light source;  
an optical fiber having a first end and a second end, the first end in communication with the light source; and  
a confocal optical probe in communication with the light source, the confocal optical probe including:  
a housing extending along a longitudinal axis between first and second ends, the housing having a maximum cross-sectional area with respect to the longitudinal axis of less than about 9 millimeters-squared;  
a base structure connected to the second end of the optical fiber, the base structure extending along the longitudinal axis in the housing and locating the second end of the optical fiber at a fixed location in relation to the housing ; and

at least one objective lens located in the housing in a fixed position proximate the second end, the at least one objective lens having a reflective portion that directs a light beam of the light source through the optical fiber towards the first end of the housing as a directed beam of light.

51. The system of claim 50, further comprising means for establishing a first focal point and a second focal point of the directed beam of light extending from the at least one objective lens on a focal axis.

52. The system of claim 51, further comprising a member disposed between the light source and the at least one objective lenses, the member having a deformable reflective portion that reflects the directed beam through the at least one objective lenses to define a first focal point of light away from the housing along a focal axis in a first operative position of the deformable reflective member, and to define a second focal point of light on the focal axis in a second operative position of the deformable reflective member.

53. The system of claim 52, wherein the member defines a plurality of focal points along the focal axis over a distance of 100 microns at a repetition rate of greater than 1 kilo-Hertz.

54. The system of claim 51, wherein the confocal optical probe is adapted to capture an image from an environment selected from a group comprising one of a biofilm in porous media; nuclear storage facilities; internally in the human body; and externally on the surface of the human body.

55. The system of claim 52, wherein the housing includes an outer diameter as measured generally transverse to the longitudinal axis of about 1.8 millimeters and the housing extends about 10 millimeters along the longitudinal axis.

55. The system of claim 52, wherein the housing includes an outer diameter as measured generally transverse to the longitudinal axis of about 1.5 millimeters and the housing extends about 10 millimeters along the longitudinal axis.
56. A method of controlling a focus of an optical device, the method comprising:  
providing a light source with an objective lens fixed in relation to each other and a housing so that a light beam from the light source along a longitudinal axis converges through the objective lens to a focal point on a focal axis; and  
translating the focal point along the focal axis.
57. The method of claim 56, wherein the translating comprises moving the focal point laterally relative to the focal axis.
58. The method of claim 56, further comprising moving the focal point laterally relative to the focal axis.
59. A method of scanning an object, the method comprising:  
establishing a fixed relationship between a light source, objective lens and a housing of an optical device so that a light beam from the light source converges through the objective lens to a focal point along a focal axis;  
translating the focal point along the focal axis during a first time interval.
60. The method of claim 59, wherein the translating comprises moving the focal point laterally relative to the focal axis during a second time interval that overlaps the first time interval.
61. The method in any one of claims 56 and 59, wherein the translating comprises translating the focal along the focal axis at a repetition rate of about 1 kilo-Hertz.

62. The method in claim 61, wherein the translating comprises translating the focal point along the focal axis at a repetition rate sufficient to provide for 200 lines in a frame of about 20 milliseconds.

63. The method in any one of claims 57 and 60, wherein the moving comprises moving the focal point laterally with respect to the focal axis at a repetition rate of 1 kilo-Hertz.

64. The method in claim 63, wherein the translating comprises translating the focal point along the focal axis at a repetition rate sufficient to provide for 200 lines in a frame of about 20 milliseconds.

65. The method of claim 64, further comprising moving the focal point laterally relative to focal axis during a second time interval that overlaps the first time interval.